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PHYSICOCHEMICAL ANALYSIS AND WATER QUALITY ASSESSMENT OF SELECTED LOCATION IN MAIDUGURI METROPOLIS USING WEIGHTED ARITHMETIC WATER QUALITY INDEX

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ABSTRACT

Access to safe drinking water is crucial for human health and well-being, however many people around the world including Nigeria face challenges in accessing clean water source. The quality of water is an important public issue and water in Maiduguri is no exception. This study focuses on evaluating the physicochemical parameters of borehole water in Maiduguri. Water samples were collected from three locations namely Polo, Moduganari and Old Maiduguri which were analyzed following standard procedure. The results showed that Temperature, pH, Total Dissolved Solids (TDS), Calcium, Chloride and Manganese levels were within safe limits of 25 ^oC, 6.5-8.5, 500 mg/l, 200-300 mg/l, 250 mg/l and 0.2 mg/l set by World Health Organization (WHO) and Nigerian Industrial Standard (NIS). However, Old Maiduguri and Moduganari had elevated levels of nitrate 35.95 mg/l and 39.95 mg/l compared to Polo with 22.6 mg/l. Dissolved oxygen levels were quite below the standards of 6.5mg/l in all three locations, while turbidity was within the acceptable limits of 5 NTU. According to the Weighted Arithmetic Index (WAI) Method, the water quality in Polo and Moduganari was classified as poor, with Water Quality Index (WQI) values of 59.67 and 51.56, respectively. On the other hand, the water quality in Old Maiduguri was classified as very poor, with a WQI value of 88.03. These results highlight the varying degrees of water quality across the study locations, emphasizing the need for interventions to improve water quality, particularly in Old Maiduguri, to ensure the well-being of the local population.

Keywords: Borehole, physicochemical, Water Quality Index, Maiduguri

INTRODUCTION

Access to adequate water supply is vital for the sustenance of life and enhancing the availability of safe drinking water can lead to noticeable improvements in health. (WHO, 2022). In the present world, approximately 1.1 billion people lack access to improve water supply and 450 million people in 29 countries are facing adequate water shortage with African nations particularly impacted by this pressing issue (Sarwar et al., 2020). Water is found extensively in almost all part of the earth and it constitute up to 75% of the earth surface, it is an essential resource needed by all living beings, including humans, animals, and plants. Water plays a crucial and irreplaceable role in nourishing and sustaining life on earth (Bello et al., 2013). Freshwater can be obtained from two primary sources: surface water, which encompasses rivers and lakes, and groundwater, which includes wells and boreholes (Katsanou & Karapanagioti, 2017). In several developing and underdeveloped countries, groundwater has been sought as a primary source to ensure the provision of safe drinking water, particularly for rural communities (Shigut et al., 2017). In Maiduguri, due to the limited rainfall, surface water is scarce hence individual, communities and governments dig well and drill boreholes in order to have access to water (Bello et al., 2013). Borehole water serves as the primary source of drinking water for the local population in Maiduguri, as only a limited number of individuals can afford and rely on purified and treated bottled water for consumption (Abubakar et al., 2018). The quality of borehole in a region is influenced by a combination of natural processes, such as the dissolution and precipitation of minerals, groundwater velocity, the quality of recharge waters, and interactions with other types of aquifers, as well as anthropogenic activities (Shigut et al., 2017). According to Akpoveta et al., (2011) "The primary causes of pollution in streams, rivers, and underground waters are predominantly human activities, which are mostly produced by bad and uncultivated individual living habits, as well as unhealthy practices of factories, industries, and corporate organizations.". The purpose of this research article is to analyze the physicochemical parameters of borehole water in three distinct location of Maiduguri: Polo, Moduganari, and Old Maiduguri. In addition, the Water Quality Index (WQI) will be used to establish the acceptability of the water for drinking and domestic activities.

MATERIALS AND METHOD

Study Area

Maiduguri is a city in northeastern Nigeria and has been a major commercial center for centuries. It is located on trade routes between Niger, Cameroon, and Chad, and it has also been a major trading center for nomadic communities in the Sahara (Bell & Card, 2021). Maiduguri covers a landmass of about 3,000 square kilometers and is located in the semi-arid region of the country, at coordinates 11.8311° N, 13.1510° E. This region receives an average annual rainfall of 600 mm, which is much lower than the average annual evapotranspiration of 2000 mm. As a result, surface water is largely seasonal, with rivers flowing for only around three months of the year (Rudiger, 2002). In Maiduguri, the typical daily temperatures range from 22 to 35°C throughout the year. However, between March and June, the average daily maximum temperature surpasses 40°C before the rainy season starts in July and spans through September (Zulum et al., 2016). Three study locations, namely Polo, Moduganari, and Old Maiduguri, were chosen as sampling sites.

Sample Collection

Water samples were collected from commercial boreholes in Polo, Moduganari, and Old Maiduguri using sterile plastic containers. A total of one liter of sample was collected from each of the three study locations. The collected samples were then transported to the laboratory under cold storage conditions for analysis within 24 hours.

Sample Analysis

The water samples were analyzed using the standard methods endorsed by the American Public Health Association (APHA, 1998) excluding Temperature and pH which were conducted on site. These procedures are well-established and widely accepted, ensuring that the measurements are accurate, reliable, and in line with the set guidelines. The parameters analyzed include; TDS, Chloride, Nitrate, Calcium, Turbidity, Dissolve Oxygen, Manganese and Magnesium.

Determination of Water Quality Index

The Weighted Arithmetic Index Method (WAI) is a Water Quality Index (WQI) that was developed by (Brown et al., 1972). The WAI is a simple to use and interpret WQI that is based on the weighted arithmetic average of individual water quality parameters and can be computed using the following steps;

The Unit Weight (Wn) factor for each parameter can be calculated using equation 1.

$$Wn = \frac{k}{s_n} \quad (1)$$

Where S_n is the standard desirable value of the n^{th} parameter and K is the constant of proportionality. K can be calculated using equation 2:

$$K = \frac{1}{\sum \frac{1}{S_n}} \quad (2)$$

The total of all specified parameter unit weights factors, Wn=1

The Water Quality Rating (Qn) using equation 3:

$$Q_n = \left[\frac{V_n - V_o}{S_n - V_o}\right] \times 100 \quad (3)$$

Where V_n is the average concentration of the n^{th} parameter, S_n is standard desirable value of the n^{th} parameter, V_o is the actual value of the parameter in pure water; which in most cases is zero except for pH 7.0 and Dissolved Oxygen 14.6mg/l (Opaluwa et al., 2020). The final Water Quality Index (WQI) can now be calculated using equation 4:

$$WQI = \frac{\sum W_n Q_n}{\sum W_n} \quad (4)$$

The Weighted Arithmetic Water Quality Index (WAI) method allows for the classification of water quality into five distinct categories. Water with a WQI of 0 to 25 is considered excellent and is assigned grade A, and water with a WQI of 100 or more is considered unsuitable for drinking and is assigned grade E (Wekesa & Otieno, 2022).

Table 1: WQI Rating and Grade

Water Quality Grading Based on WQI Rating	Water Quality Rating	Grading
0-25	Excellent water quality	A
26 – 50	Good water quality	B
51 – 75	Poor water quality	C
76 – 100	Very poor water quality	D
>100	Unsuitable for drinking purpose	E

RESULT AND DISCUSSION

Physicochemical Parameters

The average summary of the data obtained for the water samples collected from the 3 location (Polo, Moduganari, and Old Maiduguri) are shown in Table 2. The average values of the physio-chemical parameters of water samples collected from the three designated locations are presented in Table 1.

Table 2: Physicochemical Parameters Comparison of the Three Locations with Standard Limits (NIS, 2015; WHO, 2017)

Parameters	Location			WHO & NIS Standard Value
	Old Maiduguri	Polo	Moduganari	
Temperature (°C)	26.27	25.4	24.86	25 (WHO)
Ph	7.5	7.21	7.46	6.5-8.5 (NIS)
TDS (mg/l)	25	16	28	500 (NIS)
Chloride (mg/l)	57.93	29.96	39.95	250 (NIS)
Nitrate (mg/l)	35.95	22.6	39.95	50 (NIS)
Calcium (mg/l)	6.19	6.99	5.98	200-300 (WHO)
Turbidity (NTU)	0.63	0.48	1.3	5 (NIS)
Dissolve oxygen (mg/l)	1.82	2.7	4.56	6.5 (WHO)
Manganese (mg/l)	0.18	0.12	0.1	0.2 (NIS)
Magnesium (mg/l)	25.7	16.43	26.7	20 (NIS)

Temperature: The temperature of the borehole water is dependent on the climatic conditions of the specific geographic region and the time of the year. Elevated temperatures in underground water sources can lead to variations in the physical, chemical, and microbiological characteristics of the water (Opaluwa et al., 2020). The average temperature of the water sample in Polo was recorded as 25.4 °C, which is in close proximity to the WHO standard limit of 25 °C. Old Maiduguri exhibited a slightly higher average temperature of 26.27 °C, surpassing the WHO standard, while Moduganari showed a slightly lower temperature, falling below the WHO limit. Nevertheless, it is important to note that overall, the temperature of the water samples from all locations remained within acceptable limits.

pH: The pH levels of the water in all three study locations were within the NIS standard range of 6.5 to 8.5. This is important because pH is a key parameter for assessing water quality, even though it has no impact on consumers. Water with a pH below 8 is preferable for effective disinfection with chlorine, but lower pH levels can be corrosive. According to the research conducted by Zulum et al. (2016) and Abubakar et al. (2018) in Maiduguri indicate that the majority of borehole water in Maiduguri fall within the acceptable limits of 6.5 to 8.5 set by the NIS.

TDS: TDS content in water serves as a measure of salinity, and its high concentration has significant effects on water density, organisms that inhabits freshwater, and the solubility of gases like oxygen (Ogundele & OlarindeMekuleyi, 2018). Potential health effects of high TDS include damage to the central nervous system, dizziness, and paralysis of the tongue (Gupta et al., 2017). However, it is noteworthy that the study recorded a TDS value of; Polo 16 mg/l, Moduganari 28 mg/l, and Old Maiduguri 25 mg/l fell within the permissible limits set by the NIS of 500 mg/l. A comparable investigation conducted in Kyarimi, Gwange, Shehuri, Bulumkutu, and Bolori areas of Maiduguri reveals that the TDS level ranges from 85 to 121 mg/L (Abubakar, et al., 2018). This data indicates that Polo, Moduganari, and Old Maiduguri have some of the highest TDS quality in the city.

Chloride: Chloride is a significant physicochemical parameter within the aquatic ecosystem, serving as an indicator of the presence of organic waste in water when its levels exceed the desirable limits in inland water bodies (Georginia et al., 2020). The chloride levels observed in the three study locations, namely Polo (29.96 mg/L), Moduganari (39.95 mg/L), and Old Maiduguri (57.93 mg/L), are within the set limit of 250 mg/L set by the NIS, in comparison to John et al.'s (2014) analysis conducted in Wukari Town of Taraba State, where chloride levels in some boreholes reached as high as 85 mg/L, it should be noted that although the recorded levels in this research are within the permissible limit, they are significantly higher than those observed in the previous study.

Nitrate: The nitrate levels in Polo, Moduganari, and Old Maiduguri were recorded as 22.6 mg/L, 39.95 mg/L, and 35.95 mg/L, respectively. Although these levels do not exceed the standard limit of 50 mg/L set by the NIS, it is important to note that Moduganari and Old Maiduguri have nitrate concentrations that are approaching the standard limit (50 mg/l). The presence of nitrates in borehole water can be influenced by nitrification activities of microorganisms, as well as other sources such as sewage discharge, industrial effluents, and runoff from agricultural fields (Opaluwa et al., 2020). In north central Nigeria, nitrate levels are very low with average values of 2.11mg/L in a study conducted by Opaluwa et al., (2020) in Keffi and Karu Local Government Areas of Nassarawa State. The observed difference in the two results highlights how geographical location can influence the levels of physicochemical properties in borehole water.

Calcium: Calcium is an essential mineral for human health, contributing to the development of strong bones and teeth, as well as playing a role in blood clotting and muscle contraction. According to the WHO (2017), the acceptable range for calcium in drinking water is 200-300 mg/L. The results of the study conducted indicate that the average calcium levels in the three study locations, Polo (6.99 mg/L), Moduganari (5.56 mg/L), and Old Maiduguri (6.19 mg/L), are below the standard limit set by WHO. The presence of soluble calcium salts is one of the elements responsible for water hardness (Chinwendu et al., 2020). However, based on the levels observed in the three borehole water samples, the presence of calcium may not be the primary cause of water hardness.

Turbidity: Turbidity refers to the level of disorder resulting from the presences of suspended and fine insoluble particles in a water body. In the case of borehole water, turbidity can be attributed to the presence of particulate matter from various sources (Chinwendu et al., 2020). The study findings indicated that the turbidity values recorded in Polo (0.48 NTU), Moduganari (1.3 NTU), and Old Maiduguri (0.63 NTU) were all below the standard limit of 5 NTU set by the NIS. Zulum et al. (2016) conducted a comparable study in Maiduguri, which revealed a turbidity range of 0.13 to 0.75 NTU across seven different locations. This suggests that the water in Maiduguri is relatively clear and less turbid.

Dissolve Oxygen: Dissolved oxygen levels serve as an indicator of changes in biological parameters, reflecting the occurrence of aerobic or anaerobic phenomena. When the dissolved oxygen levels are very low, it can lead to anaerobic conditions, which may result in unpleasant odors (Gupta et al., 2017). The study revealed that Old Maiduguri (1.82 mg/L) and Polo (2.7 mg/L) have very poor levels of dissolved oxygen, which may lead to unpleasant odors. However, Moduganari had a more considerable amount of DO (4.56 mg/L), approaching the WHO limit of 6.5 mg/L.

Manganese: Based on the NIS guidelines, manganese concentrations above 0.2 mg/L can potentially cause neurological and gastrointestinal disorders. In the three study locations (Polo, Moduganari, and Old Maiduguri), the concentrations of manganese were measured as 0.12 mg/L, 0.1 mg/L, and 0.18 mg/L, respectively. These findings points out a high level of manganese in the three water samples. This resesult are not far different from the one

Magnesium: Magnesium, along with calcium, is commonly associated with water hardness (Chinwendu et al., 2020). In the conducted study, only Polo had a magnesium level (16.43 mg/L) below the standard limit of 20 mg/L set by the NIS. However, both Old Maiduguri and Moduganari had magnesium levels of 25.7 mg/L and 26.7 mg/L, respectively, which exceed the standard limit. In contrast to the south-western region of Nigeria, where the magnesium level was found to be below 4.19 mg/L in a study analyzing the physicochemical properties of 21 wells, the average magnesium level in those wells was recorded at 2.65 mg/L (Olusola et al., 2017). The elevated levels of magnesium in all three study locations, combined with the levels of calcium, contribute to the hardness of the water.

Table 3: Water Quality Evaluation

Parameters	1/Sn	Wn	Old Maiduguri		Polo		Moduganari	
			Qn	WnQn	Qn	WnQn	Qn	WnQn
pH	0.118	0.021	33.333	0.706	14.000	0.297	30.667	0.650
TDS	0.002	0.000	5.000	0.002	3.200	0.001	5.600	0.002
Chloride	0.004	0.001	23.172	0.017	11.984	0.009	15.980	0.012
Nitrate	0.020	0.004	71.900	0.259	45.200	0.163	79.900	0.288
Calcium	0.003	0.001	2.063	0.001	2.330	0.001	1.993	0.001

Turbidity	0.200	0.036	12.600	0.454	9.600	0.346	26.000	0.937
Dissolve Oxygen	0.154	0.028	157.778	4.373	146.914	4.072	123.951	3.435
Manganese	5.000	0.901	90.000	81.069	60.000	54.046	50.000	45.038
Magnesium	0.050	0.009	128.500	1.157	82.150	0.740	133.500	1.203
Σ	5.551	1.000	88.039		59.674		51.566	
WQI			88.039		59.674		51.566	

Table 4: Summary of Water Quality Index Across Study Locations

Study Location	WQI Value	WQI Class
Old Maiduguri	88.03	Very poor water quality
Polo	59.67	Poor water quality
Moduganari	51.56	Poor water quality

Among the study locations, Old Maiduguri obtained the highest Water Quality Index (WQI) value of 88.03, classifying its water quality as very poor. This indicates that the water in Old Maiduguri is not suitable for drinking but may still be used for other domestic activities with caution. Polo and Moduganari, although not as severe as Old Maiduguri, still exhibited poor water quality with WQI values of 59.67 and 51.56, respectively. These findings highlight the need for measures to improve water quality in these areas to ensure the health and well-being of the local population.

CONCLUSION

In this study, the physicochemical parameters of borehole water in Maiduguri, Nigeria, were evaluated. The results revealed that the temperature, pH, TDS, calcium, chloride, manganese and turbidity levels were within the safe limits recommended by WHO and NSDWQ. However, elevated nitrate levels were observed in Old Maiduguri and Moduganari compared to Polo. On the other hand, dissolved oxygen levels fell below the standard limit in all 3 locations, while in Old Maiduguri and Moduganari magnesium level are above the standard limits. The Water Quality Index (WQI) classified the water quality in Polo and Moduganari as poor, with values of 59.67 and 51.56, respectively. In contrast, Old Maiduguri was categorized as very poor, with a WQI value of 88.03. These findings emphasize the varying degrees of water quality among the study locations and highlight the urgent need for interventions to improve water quality, particularly in Old Maiduguri, in order to ensure the protection of the community residing in the area.

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